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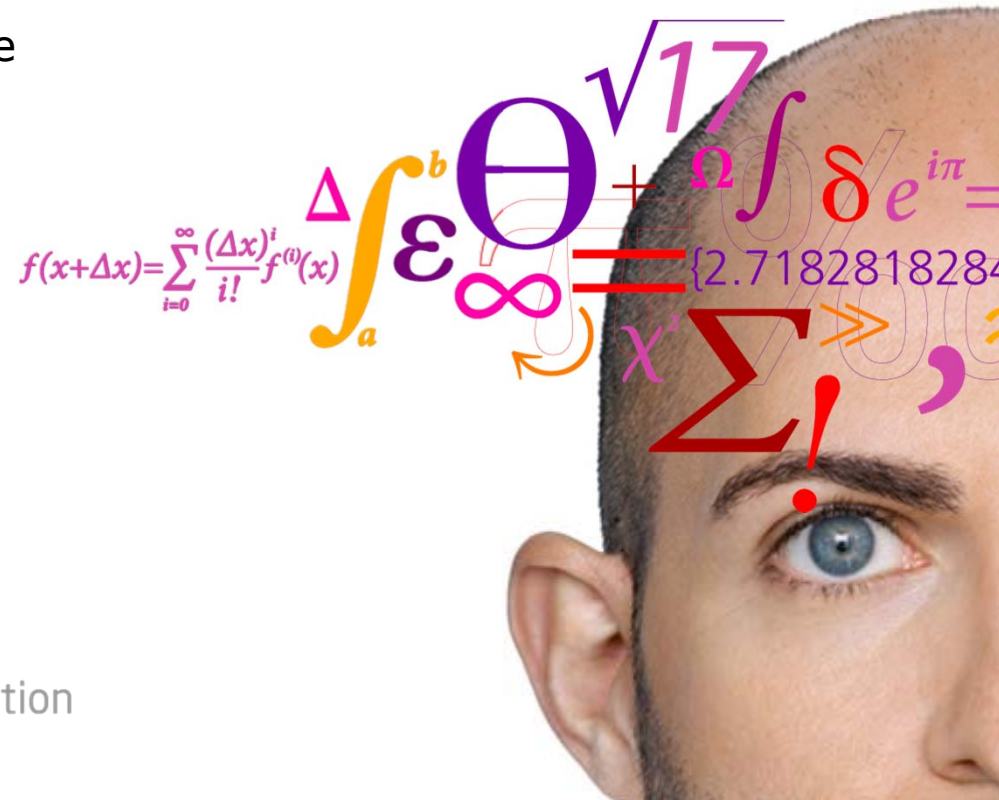
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An Arduino-Based Hardware Lock and Sensor Data Collection System for Cleanroom Equipment

Leif S. Johansen, Henrik Nyholt, Jens Hemmingsen, Thøger Eskildsen & Jörg Hübner

UGIM 2014, Cambridge, MA, 17 June



Brief Introduction to DTU Danchip



- Danish national centre for micro- and nanofabrication, founded 1992
- A unit under the Danish Technical University (DTU)
- 40+ staff
- ISO 9001 certified since 2011
- 14 500 ft² (1350 m²) class 10, 100 & 1000 space
- 250 registered users at any given time
- Ca. 140 new users per year
- 80/20% academic/commercial use
- From basic research to small-scale production
- 140+ pieces of equipment
- Pieces, 2", 4", 6" & 8"



DTU Danchip, Technical University of Denmark



DTU Danchip's Payment Model



- Payment per cleanroom hour. 20 hours/month cap
- Tool usage payment
 - Class A tools (UV litho, furnaces, plating, etc.): Low fee
 - Class B tools (Thin film dep. and etch): Medium fee
 - Class C tools (DUV stepper, e-beam writer): High fee
 - Class F tools (microscopes, wet benches): Included in access fee
- Cleanroom and tool rates are depending on project type:
 - Academic: No fee
 - Academic with external funding: Reduced fee
 - Commercial: Commercial fee
- Some materials not included in tool rate: Gold, wafers & photomasks
- In the future: Expensive photoresists will be billed by consumption (1 G ZEP520: 100 000 \$)
- All tool and cleanroom hours are logged via LabManager, our lab usage management system
- LabManager data forms the basis for calculation of hourly rates

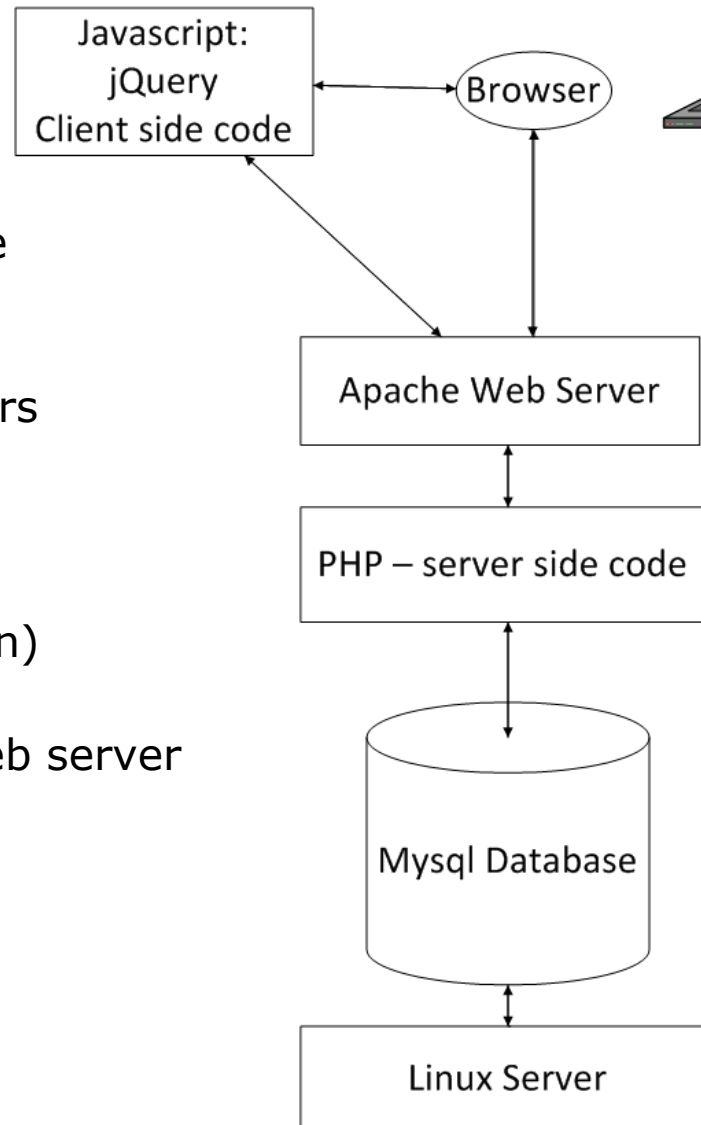


LabManager - Architecture



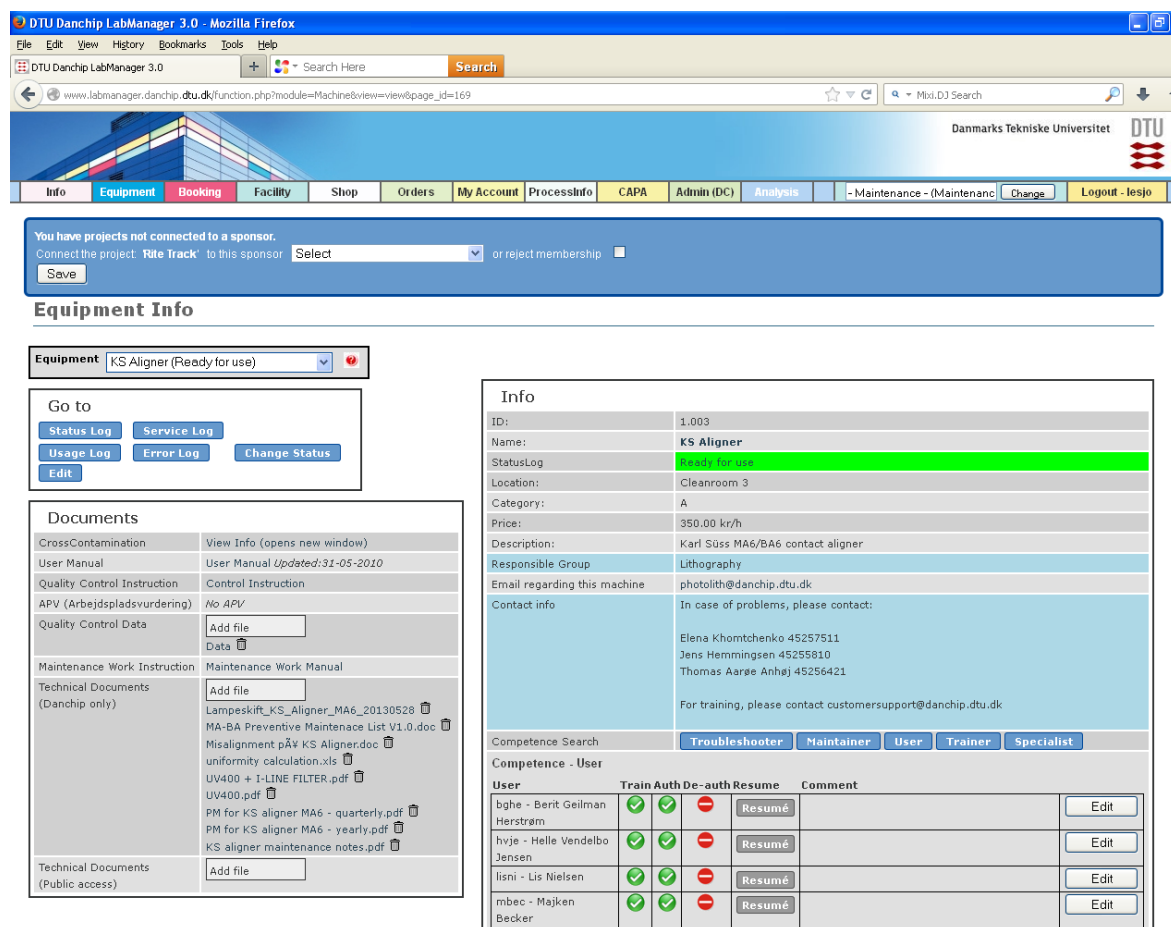
Users/Employees

- LabManager: Proprietary lab usage management system
- Gradually developed over 10+ years
- Browser based
 - No s/w installation needed
 - Accessible anywhere (with login)
- Browser interfaces with Apache web server
- LabManager written in PHP
 - Not compiled
 - Easier to change code



LabManager – Functions

- Operator manuals
- Technical documents (user accessible)
- Technical documents (Danchip staff only)
- Maintenance manuals
- Safety instructions
- Contact persons
- Tool status
- Booking calendar
- Start/stop
- Logbooks (partially)
- Web shop (wafers etc.)
- Tool usage statistics
- Uptime analysis
- Bottleneck finder
- Invoicing
- CAPA handling (Danchip staff only)
- Cross contamination (upcoming)



DTU Danchip LabManager 3.0 - Mozilla Firefox

File Edit View History Bookmarks Tools Help

DTU Danchip LabManager 3.0

www.labmanager.danchip.dtu.dk/function.php?module=Machine&view=view&page_id=169

Danmarks Tekniske Universitet DTU

Info Equipment Booking Facility Shop Orders My Account ProcessInfo CAPA Admin (DC) Analysis Maintenance - (Maintenanc Change Logout - lesjo

You have projects not connected to a sponsor. Connect the project 'Rite Track' to this sponsor: Select or reject membership Save

Equipment Info

Equipment: KS Aligner (Ready for use)

Go to: Status Log Service Log Usage Log Error Log Change Status Edit

Documents

CrossContamination	View Info (opens new window)
User Manual	User Manual Updated:31-05-2010
Quality Control Instruction	Control Instruction
APV (Arbejdspladsvurdering)	No APV
Quality Control Data	Add file Data
Maintenance Work Instruction	Maintenance Work Manual
Technical Documents (Danchip only)	Add file Lampeskift_KS_Aligner_MA6_20130526 MA-BA Preventive Maintenance List V1.0.doc Misalignment på KS Aligner.doc uniformity calculation.xls UV400 + 1-LINE FILTER.pdf UV400.pdf PM for KS aligner MA6 - quarterly.pdf PM for KS aligner MA6 - yearly.pdf KS aligner maintenance notes.pdf
Technical Documents (Public access)	Add file

Info

ID:	1.003
Name:	KS Aligner
StatusLog:	Ready for use
Location:	Cleanroom 3
Category:	A
Price:	350.00 kr/h
Description:	Karl Süss MA6/BA6 contact aligner
Responsible Group:	Lithography
Email regarding this machine:	photolith@danchip.dtu.dk
Contact info:	In case of problems, please contact: Elena Khomtchenko 45257511 Jens Hemmingsen 45255810 Thomas Aarseth 45256421 For training, please contact customersupport@danchip.dtu.dk

Competence Search: Troubleshooter Maintainer User Trainer Specialist

Competence - User

User	Train	Auth	De-auth	Resume	Comment	Edit
bghe - Berit Geilman Herstrøm	✓	✓	✗	Resumé		Edit
hvj - Helle Vendelbo Jensen	✓	✓	✗	Resumé		Edit
linsi - Lis Nielsen	✓	✓	✗	Resumé		Edit
mbec - Majken Becker	✓	✓	✗	Resumé		Edit

Start/Stop

- Equipment will be put in "in use" mode on the info page
- The chosen project will be billed
- Tool usage statistics can be extracted

Use Equipment

Customer	<input type="text" value="LSJ - lesjo - (Leif Johansen)"/>	<input type="button" value="Get Last"/>
Customers Projects	<input type="text" value="Process Develop"/>	
Equipment	<input type="text" value="DUV Stepper"/>	<input type="button" value="Start to use"/>

BUT!

- People "forget" to Start/Stop
- No overview over actual tool usage
 - *"Comparing log files with registrations made me lose my faith in humanity"*
- Unauthorized users accessing tools they are not trained to use
- Impossible to do proper price modelling, bottle neck analysis, etc.
- Funding of DTU Danchip jeopardized
- Unable to troubleshoot breakdowns (who did what, and when?)
- Something has to be done
- **Lock 'em up!** (The tools – not the users)



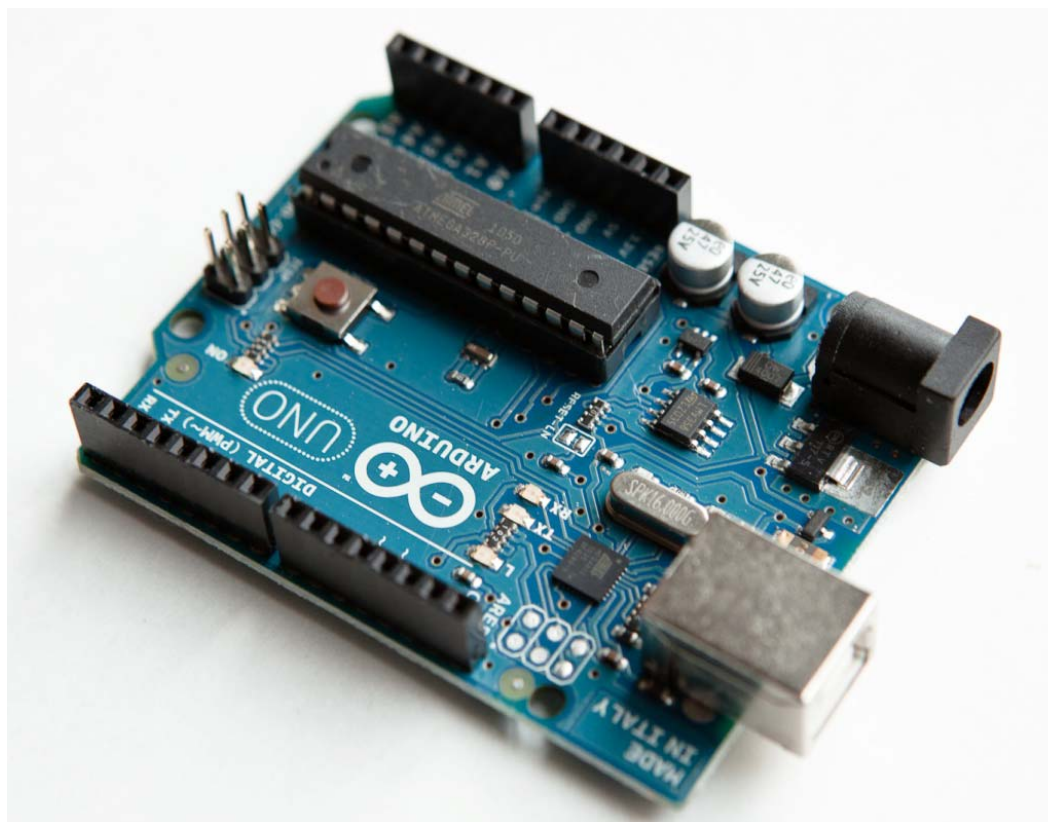
Candidates for Hardware Lock system

- Web IP switches:

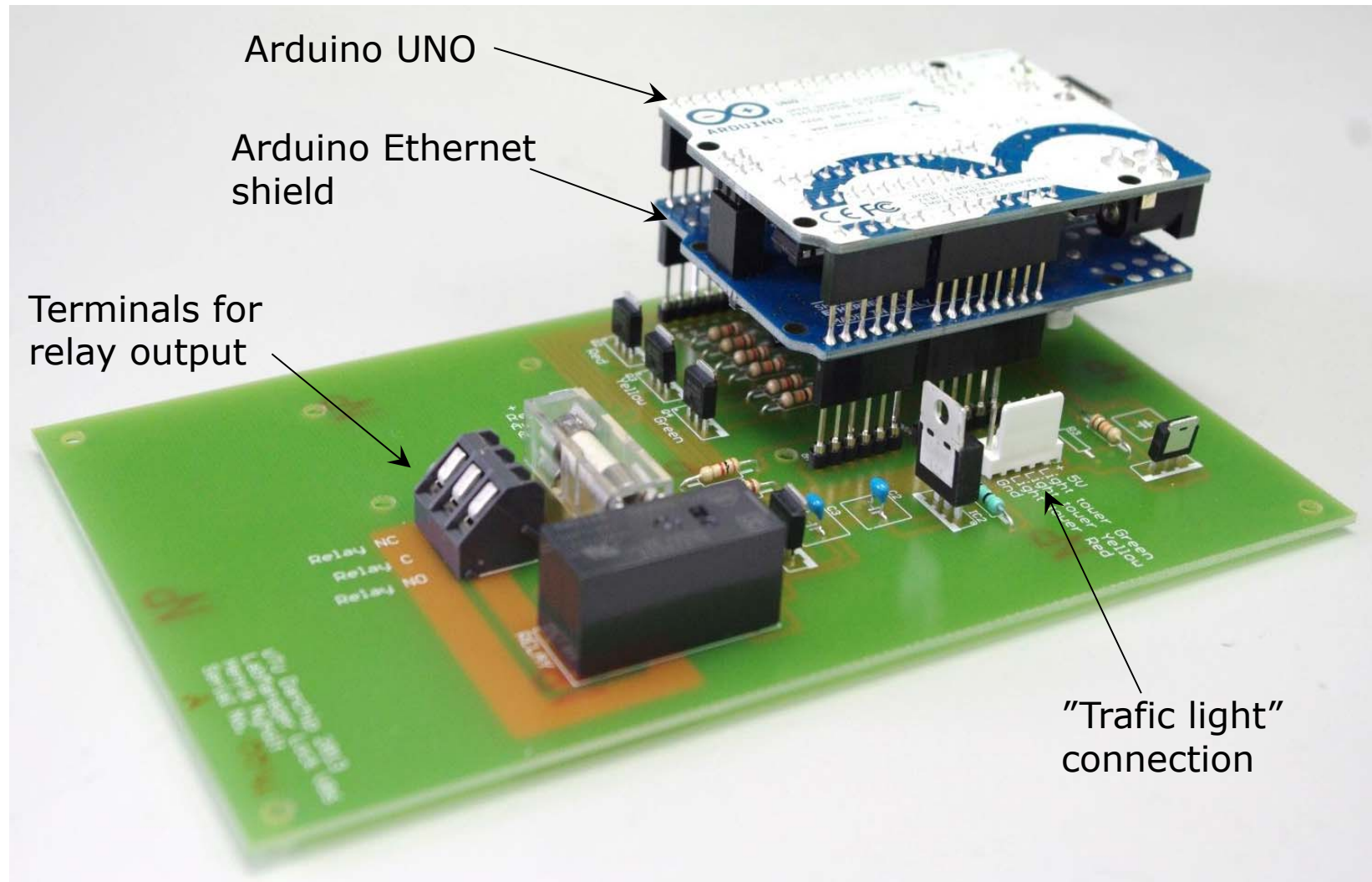


The Arduino Microcontroller - Another Good Candidate to Build a Hardware Lock Around

- 8 bit processor
- 35 kB RAM (in flash, SRAM & EEPROM)
- 16MHz
- 14 digital I/Os
- 6 analogue inputs
- Few μW – 2.5W
- Powered over Ethernet (POE)
- Easy to program
- Price 25 USD
- More flexible than ordinary Ethernet switches
- Extra functionality



The LabManager Lock



The LabManager Lock in its Cabinet



- WxHxD: 4x2.5x6 in³ (10x7x16 cm³)
- BOM: >100 \$. More expensive than a web switch
- Assembled in house by student helpers
- Easily installable in a service area
- POE: No extra power needed
- Disable/enable
 - Screen power
 - Interlock switch
 - Shutter (aligner)
 - Power (simple tools)
 - Solenoid actuated lock
 - RF generator



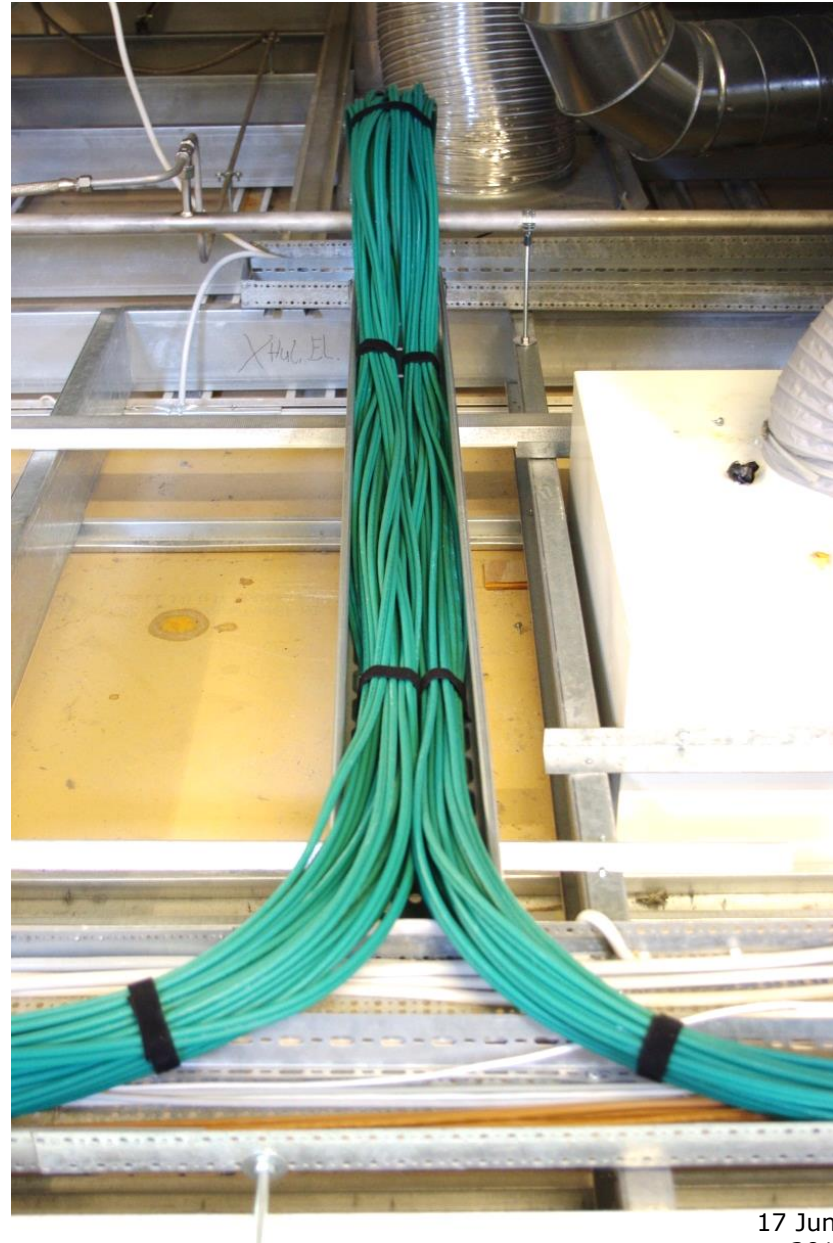
Traffic Light

- Placed next to tool's user interface
(PC screen, furnace door, loadlock etc.)



Infrastructure Investments: POE Cables

- 140 PDS cables, category 6A
- POE switches
- Price: Ca. 45 000 \$
- Not only for LabManager locks
- Also for safety warning signs
- WLAN not preferred



LabManager Lock - Front View

DIN connector:
"Traffic light"

USB connector:
Programming



POE LAN connector:
Power and comm's

LabManager Lock - Rear View, Relay Type

Relay
connection

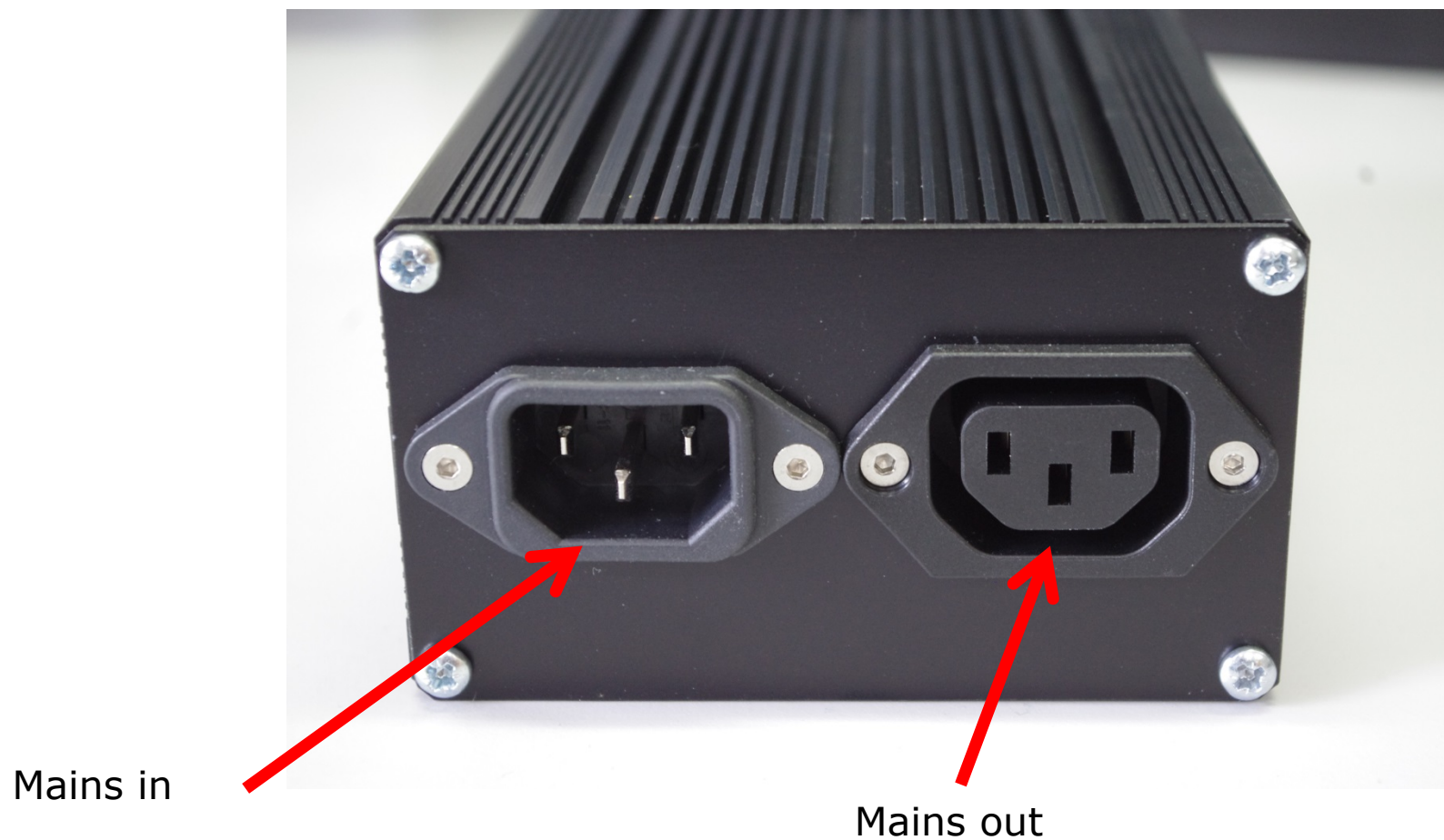


Rear View – 5 V Control Signal

5 Volt control
signal



Rear View, Mains Switch



Same Platform – CDA Pressure Gauge

- Portable point of use CDA pressure gauge
- CDA readouts are logged in a database via Ethernet
- Also made in a point of use vacuum gauge version



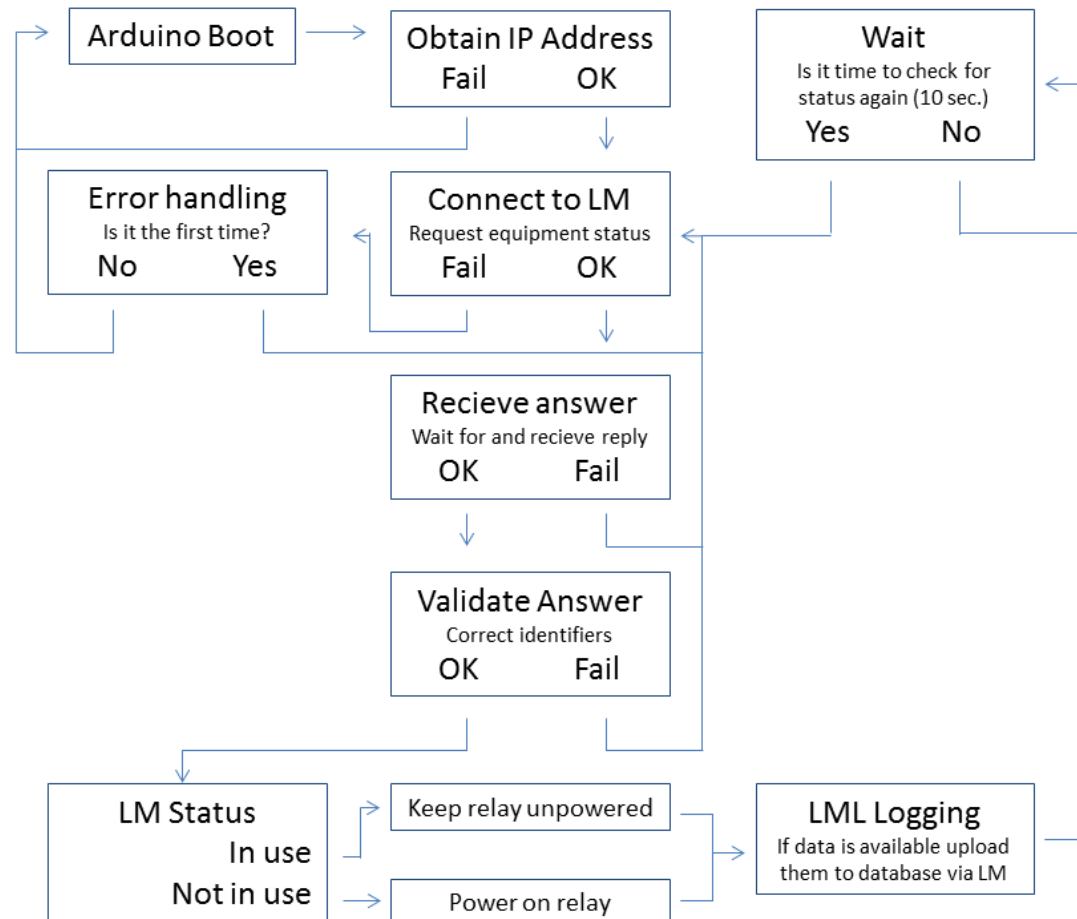
Present Project: Calculation of Resist Consumption

- DUV resist coater
- Expensive resist
- LM Lock analogue input:
 - Reading of resist canister weight scale
 1. Read canister weight at tool logon
 2. Read canister weight at tool logoff
 3. Calculate resist consumption
 4. Issue bill for consumed material
- Next project: Automatic status change in LabManager via digital outputs from tool



If the Network is Down...

- Blocked equipment upsets users
- The hardware lock checks the machine's status in LabManager every 10th sec
- If the lock receives no answer from the software on status, the lock is unlocked (happy hour in the cleanroom)



LabManager - Competences

Competence - Authorized Users																						
User	Trained	Authorized	De-authorized	Resume																		
elkh - Elena Khomtchenko				<div>Resumé</div>																		
taran - Thomas Aarøe Anhøj				<div>Resumé</div>																		
makei - Matthias Keil				<div>Hide</div> <table><tr><th>Change</th><th>Time</th><th>Changed By</th></tr><tr><td>authorized: <i>trainer</i></td><td>2013-10-09 16:00:40</td><td>elkh</td></tr><tr><td>added Training: <i>trainer</i></td><td>2013-10-09 16:00:38</td><td>elkh</td></tr><tr><td>authorized: <i>user</i></td><td>2013-10-09 16:00:37</td><td>elkh</td></tr><tr><td>added Training: <i>user</i></td><td>2013-10-09 16:00:35</td><td>elkh</td></tr><tr><td>authorized: <i>maintainer</i></td><td>2013-10-09 16:00:33</td><td>elkh</td></tr></table>	Change	Time	Changed By	authorized: <i>trainer</i>	2013-10-09 16:00:40	elkh	added Training: <i>trainer</i>	2013-10-09 16:00:38	elkh	authorized: <i>user</i>	2013-10-09 16:00:37	elkh	added Training: <i>user</i>	2013-10-09 16:00:35	elkh	authorized: <i>maintainer</i>	2013-10-09 16:00:33	elkh
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authorized: <i>user</i>	2013-10-09 16:00:37	elkh																				
added Training: <i>user</i>	2013-10-09 16:00:35	elkh																				
authorized: <i>maintainer</i>	2013-10-09 16:00:33	elkh																				
<div><ul style="list-style-type: none">• Only authorized users can start equipment• Automatic de-authorization after 9 months without usage• "Bad boys" can be immediately de-authorized</div>																						

Results so far

- 48 hardware locks installed 1st half 2014
- Some tools are clearly used “more” (e.g. mask aligners, hot plates, SEMs)
- Usage of some tools fluctuates– difficult to say yet
- We caught a few culprits – including “goldfinger”

Summary

- A hardware lock has been developed – built around an Arduino UNO board
- Controlled (locked/unlocked) from LabManager software
- Can only be unlocked by authorized users
- Different lock versions for different tool types
- Flexible solution capable of also reading sensor data and tool status
- Resilient to network breakdowns
- Not cheapest solution
- Maybe not for everyone



Thanks to the Guys who Did all the Real Work



- Henrik Nyholt. Basic idea concept, hardware design and construction, microcontroller programming.



- Thøger Eskildsen. PHP-programming of LabManager software.



- Jens Hemmingsen. Hardware design and construction.

Thank you for your attention...

